Supplementary Methods for "Comment on 'Nuclear Emissions During Self-Nucleated Acoustic Cavitation' "

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Monte Carlo methods. Figure 1 shows the geometry used in the "2.45 MeV w/shielding" detector response simulation. The cavitation fluid, modeled as described in footnote 13 of [1], consists of carbon, deuterium, chlorine, oxygen, nitrogen, and uranium. The simulation, using GEANT4 [2], includes all relevant neutron interactions, particularly elastic scattering, thermal capture, $(n, n'\gamma)$ scattering, and neutron-induced fission.

To calculate the response function, neutrons of energy 2.45 MeV, emitted isotropically from the center of the flask, scatter through the materials. When a neutron elastically scatters protons in the liquid scintillator, the recoil energies are converted to equivalent electron energies [3], summed, and then smeared according to the detector's resolution function, eventually obtaining the response function $g(E_{ee})$.

In the same manner, I calculate the other response functions with the following changes: the "2.45 MeV" simulation does not include the paraffin shield, and the radioisotope [4, 5] simulations "Cf-252" and "PuBe" assume there are no intervening scattering materials between the sources and the detector.

Statistical methods. Following the notation of [6], the raw data from Fig. 9(b) of [1] are

$$\begin{aligned} n_k &= \text{"cavitation off" counts in channel } k \\ n'_k &= \text{"cavitation on" counts in channel } k. \end{aligned}$$

Each run is 300 s in duration, and Fig. 4 of [7] shows the background-subtracted signal $n'_k - n_k$.

The n_k background data are modeled by a sum of two exponentials, and the n'_k data are modeled by the same background function plus the scaled response function,

$$\begin{aligned} y_k &= A_1 \exp(-k/A_2) + A_3 \exp(-k/A_4) \\ y'_k &= y_k + A_5\, g_k. \end{aligned}$$

The binned response function g_k, is found by averaging $g(E_{ee})$ over the energy range of channel k.

Then, the Poisson likelihood chi-square [6] is

$$\chi^2_{\lambda,p} = 2 \sum_{k=11}^{249} \left[\phi_k + \phi'_k\right],$$

where

$$\begin{aligned} \phi_k &= y_k - n_k + n_k \ln(n_k/y_k) \\ \phi'_k &= y'_k - n'_k + n'_k \ln(n'_k/y'_k). \end{aligned}$$

Note that, under proper conditions [6], $\chi^2_{\lambda,p}$ asymptotically approaches a χ^2 distribution. Moreover, better fits give lower values of $\chi^2_{\lambda,p}$. Minimization [8] of $\chi^2_{\lambda,p}$ determines the five fit parameters A_i. See Fig. 2(a) for the fit using the "Cf-252" response function.

To determine the distribution $f(\chi^2_{\lambda,p})$ for a given fit, I sample from many synthetic data sets, each chosen, for $k = 11, \ldots, 249$, from Poisson distributions of mean value y_k and y'_k . In the Comment, I report the goodness-of-fit as a Z-value, defined by

$$\int_{\text{obs. } \chi^2_{\lambda,p}}^{\infty} f(\chi^2)\, d\chi^2 = \frac{1}{\sqrt{2\pi}} \int_Z^{\infty} e^{-t^2/2}\, dt,$$

which expresses the observed value of $\chi^2_{\lambda,p}$ in terms of the equivalent number of standard deviations from the mean of a normal distribution. As shown in Fig. 2(b), the observed value of $\chi^2_{\lambda,p}$ for the "Cf-252" fit is within one equivalent standard deviation and is therefore statistically consistent. The other three fits are outside five equivalent standard deviations, and are therefore statistically inconsistent.

[1] R. P. Taleyarkhan *et al.*, EPAPS Document No. E-PRLTAO-96-019605.
[2] S. Agostinelli *et al.*, Nucl. Instr. and Meth. A **506**, 250 (2003).
[3] V. V. Verbinski, W. R. Burrus, T. A. Love, W. Zobel, N. W. Hill, and R. Textor, Nucl. Instr. and Meth. **65**, 8 (1968).
[4] A. Lajtai, P. P. Dyachenko, V. N. Kononov, and E. A. Seregina, Nucl. Instr. and Meth. A **293**, 555 (1990).
[5] M. E. Anderson and R. A. Neff, Nucl. Instr. and Meth. **99**, 231 (1972).
[6] S. Baker and R. D. Cousins, Nucl. Instr. and Meth. **221**, 437 (1984).
[7] R. P. Taleyarkhan, C. D. West, R. T. Lahey, Jr., R. I. Nigmatulin, R. C. Block, and Y. Xu, Phys. Rev. Lett. **96**, 034301 (2006).
[8] F. James and M. Roos, Comput. Phys. Comm. **10**, 343 (1975).

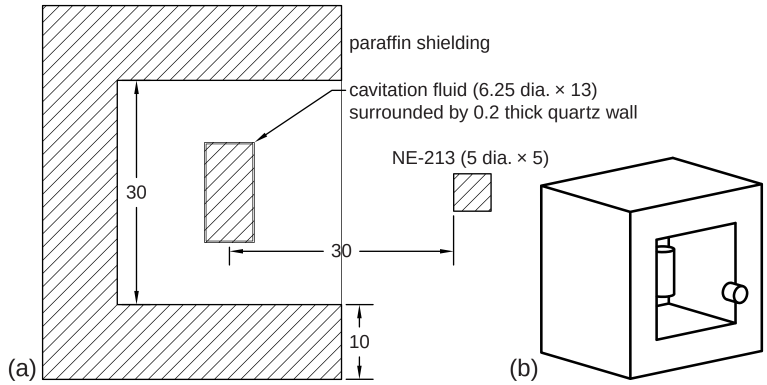

FIG. 1: Monte Carlo geometry. All dimensions in cm. (a) Section view. (b) Perspective view.

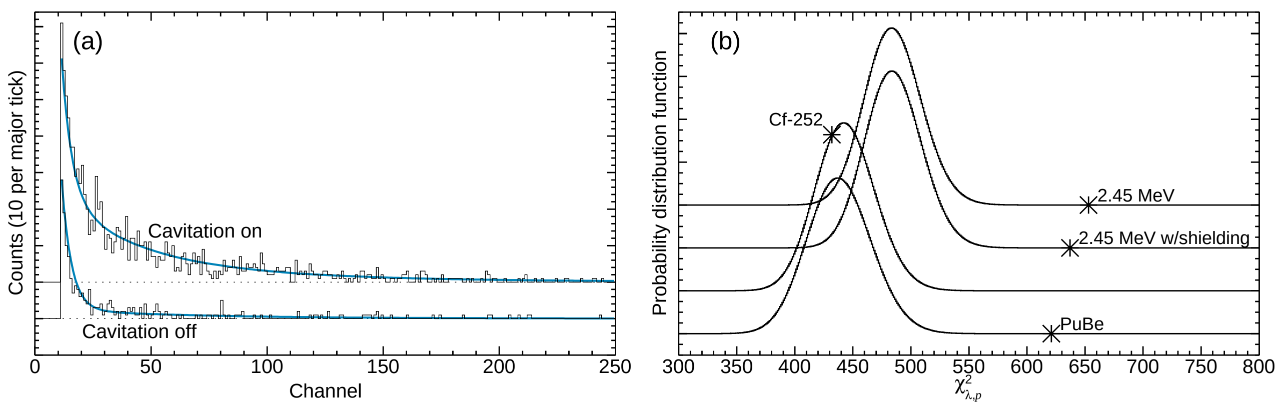

FIG. 2: Fit statistics. (a) Fit using the simulated ^{252}Cf response function for g_k. The histograms are n_k and n'_k, and the smooth blue lines are theoretical curves y_k and y'_k. The minimized value of $\chi^2_{\lambda,p}$ is 432. For clarity, the two graphs are offset by ten counts. (b) Numerically sampled distributions of $\chi^2_{\lambda,p}$ for the four hypotheses. Observed values of $\chi^2_{\lambda,p}$ are shown.